Retarding Browning in Explosion-Puffed Potatoes

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R & D REPORT

Explosion-puffing saves costly drying time in processing quick-cooking dehydrated fruits and vegetables. When the process is applied to potato pieces, however, the puffing step in particular accelerates the browning reaction to the point of producing readily detected off-flavors. The problem has been solved by introducing CO_2 into the puffing gun along with superheated steam.

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NON-ENZYMATIC BROWNING, a phenomenon occurring in many food products, plays an important role in product quality. The results in some cases are desirable: commodities such as bread, chocolate and beer, for example, owe their distinctive characteristics and wide acceptability in part to this chemical reaction. In food dehydration, however, the results are generally undersirable, and pose severe processing and storage problems.

The explosive puffing process (Cording et al, 1962), developed at our Eastern Regional Research Center, is a means of preparing quick-cooking dehydrated fruits and vegetables. The process has been applied successfully to carrots, beets, rutabagas, red and green pepper pieces, celery slices, apple pieces and blueberries. The procedure, as applied to white potatoes, is described in detail in an earlier publication (Turkot et al, 1967) which includes an estimate of cost.

Briefly, it comprises hot air-drying of potato pieces conventionally at atmospheric pressure to an intermediate moisture content of 25-30%. The partially dried pieces are placed in a puffing gun, which is a rotary cylinder with a pressure-tight hinged lid, capable of being opened instantly. The pieces are heated in the gun during rotation, by continuously passing superheated steam under pressure through the gun contents.

Thus, the water within the partially-dried pieces is brought rapidly (in about 1 min) to a temperature above its atmospheric boiling point. When the gun lid is opened instantly, a fraction of the water flashes into steam, creating a porous structure in the pieces.

Because of the porosity, final drying to 6% moisture content can be achieved for the puffed pieces in about half the time required to dry conventional non-puffed pieces (Eisenhardt, N.H. et al, 1962). The finally-dried pieces are then capable of complete rehydration by simmering for 5 min in water.

Potatoes Brown Readily

Of all the fruits and vegetables that have been explosion-puffed, potatoes exhibit the greatest susceptibility to the adverse effects of the browning reaction. They contain the reactants required and because their own natural flavor is bland, browning off-flavors are easily detected.

From the beginning of our research we have been aware of browning off-flavors in varying degrees as determined by organoleptic evaluation. The most common of the browning reactions is the Maillard reaction (Maillard, L.C., 1912). This amino-carbonyl reaction involves combinations of aldehydes or reducing sugars with amino acids, peptides or proteins (Borgstrom, G., 1968). Flavor is affected significantly by this combination. The Strecker degradation, the third step in the Maillard reaction, contributes most significantly to the odor (Holtermand, A., 1966). This degradation, although not essential to the overall Maillard reaction, results in the formation of odorous aldehydes and in the loss of CO_2 from the system.

Flavor improvement was mandatory since white potatoes should be included in explosion-puffed commodities because year-round availability of this raw material favorably affects the economic feasibility. This paper describes research on the puffing process on white potatoes which has resulted in reduction of browning off-flavors to acceptable levels.

Preparing the Raw Material

Potatoes were immersed in a 20% (by weight) sodium hydroxide solution to loosen the skins. The skins were then removed by passing them through a rotary rod-reel washer with high-pressure water jets. The peeled potatoes were hand trimmed to remove rot, sunburn, bruised tissue and other blemishes. They were placed in wire baskets and dipped in a solution containing ½% sodium bicarbonate and ½% citric acid to prevent enzymatic browning. Unless otherwise specified, the subsequent use of the word "dipped" has the foregoing connotation.

Peeled potatoes were cut into nominal ⅜ in. cubes, dipped, and screened over a screen having $3/16$ x 2 in. openings to remove slivers. The dice were washed thoroughly to remove surface starch and were

TABLE 1—2- (+) 3-Methyl Butanal Levels at Various Stages of Processing (Values Represent Areas Under Peaks of G.L.C.)

Processing Stage	Area Under Peaks
Raw Potato	1.9
After Precook	0.7
After Cool and Blanch	0.9
After Prelim. Drying	0.6
After Equilibration	1.0
After Puffing	13.7

TABLE 2—2-Methyl Propanal Levels at Various Levels of Non-Candensible Gases in Heating Stream

Steam Rate lb/min	Rate of Gas Added lb/min	Values Representing 2-Methyl Propanal Levels Under Peaks of G.L.C.		
		N_2	CO_2	Air
1.0	0.0	41.1	41.1	41.1
0.8	0.2	23.5	28.1	15.8
0.5	0.5	12.1	10.3	9.0
0.4	0.6	6.9	8.5	6.9

dipped again. They were then precooked (Cording et al, 1955) at 160F for 15 min and cooled (Cording et al, 1959) for a period of 10 min in cold water (below 70F).

These treatments respectively gelatinize the starch and retrograde the amylose to reduce its stickiness should cell rupture occur during rehydration. The dice were blanched in flowing steam at atmospheric pressure for 15 min. They were then held in a final sulfite dip (¼% $NaHSO_3$, ¼% Na_2SO_3) for 1 min to prevent non-enzymatic browning during the first drying cycle. They were dried to 27% moisture content in a batch, through-flow drier at an air temperature of 200F.

To insure uniform moisture distribution within and among pieces, they were held in closed containers for a period of 24 to 36 hr. When dice are dried in continuous belt driers of commercial design, equilibration times of only 2 or 3 hr (considered a reasonable holding time in commercial operation) are needed.

Explosion-Puffing

All experiments were made with 5-lb charges in the puffing gun. Puffing conditions were as follows:

1. Skin (wall) temperature 320F, maintained by application of external heat to prevent condensation of steam on the inner wall.
2. Superheated steam temperature: 380F.
3. Steam pressure in gun: 65 psig.
4. Residence time of potato dice in gun: 1.5 min.

After puffing, the porous potato dice were dried to approximately 6% moisture content in a batch through-flow hot air drier using an air temperature of 150F.

Preliminary experiments, in which the product was evaluated organoleptically at each stage of processing, pinpointed the explosion-puffing step as the site of the off-flavor development. Following this, vapors emitted during cooking were collected and analyzed by a gas chromatograph coupled to a mass spectrometer for vapor component identification (Filipic, V. J., 1967). Components were identified as Strecker aldehydes and autoxidation aldehydes. Thus the browning off-flavor was attributed to 2-methyl propanal (2 MP), and 2- and 3-methyl butanal (2+3 MB).

Since a loss of CO_2 from the system is a characteristic of the Strecker degradation, it was reasoned that, by the Law of Mass Action, the introduction of CO_2 into the gun along with the superheated steam would tend to reverse or impede the reaction. The use of other gases was also tested.

Product Evaluation

Products were analyzed by a gas-liquid chromatographic method (Buttery, R. G. and Teranishi, R., 1963) as modified at ERRL (Filipic, V. J., 1967). On all samples, 2 MP or 2 + 3 MB was determined. The amount of each component reported corresponds to the area under its respective peak. At the time the results reported in Tables 1 and 2 were determined, the method had not yet been modified to include an internal standard (Sapers, et al, 1970). Therefore, the results in each table can be compared with each other but those of the two tables cannot be cross-compared.

Conclusions

Data shown in Table 1 confirm results of organoleptic tests which showed that the off-flavors originate during the puffing step. These data on 2 + 3 MB levels in the potato show levels of 1.9 or lower at all stages preceding puffing, but after puffing a highly significant rise to a level of 13.7 is observed.

To discover whether or not the addition of one of the Strecker degradation products, CO_2, would limit or reverse the reaction producing the unwanted aldehydes, it was added to the superheated steam. As the CO_2 flow rate was increased (Table 2), the superheated steam flow was reduced and the amount of heat available from steam condensing on the potato pieces, therefore, also decreased.

From Table 2 it is evident that the level of 2 MP in the product decreased as the CO_2 level was increased. At the 0.2 lb per min level, the odor typical of browning was detectable on puffing. At the 0.5 lb per min level the product was puffed and was acceptable, as judged by taste and odor, and the 2 MP level was reduced materially. At the 0.6 lb per min level, no "off" odor or taste was detectable.

The product was not puffed, however, because the low level of steam did not supply sufficient latent heat to cause vaporization of contained water on pressure release. A balance of superheated steam to supply heat and of CO_2 to retard aldehyde formation must be maintained. Subsequent pilot plant tests have shown 0.65 lb per min of steam to 0.35 lb per min of gas to be optimum.

It was suggested that the improvement may have been due to the CO_2 displacing oxygen in the system. The test was repeated using nitrogen at the same levels as for CO_2. As is shown in Table 2, nitrogen lowered the aldehyde levels to about the same degree as CO_2. The Mass Action hypothesis was thus ruled out.

If oxygen were involved, the substitution of air for CO_2 or nitrogen should increase the aldehyde levels. When this was tried, as shown in Table 2, the levels were also lowered. The use of air is impractical, however, because oxidative off-flavors develop due to oxidation of the potato lipids.

The mechanism whereby the retardation is effected has not been discovered. Nevertheless, a practical method has been found for retarding the browning reaction in the explosion puffing of potatoes, reducing the off-flavors to a level of acceptability. □

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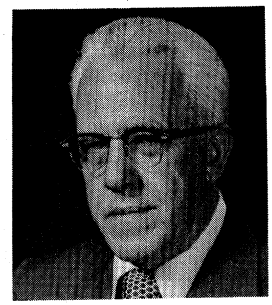

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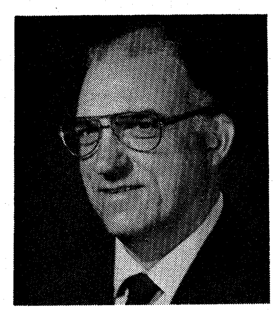

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